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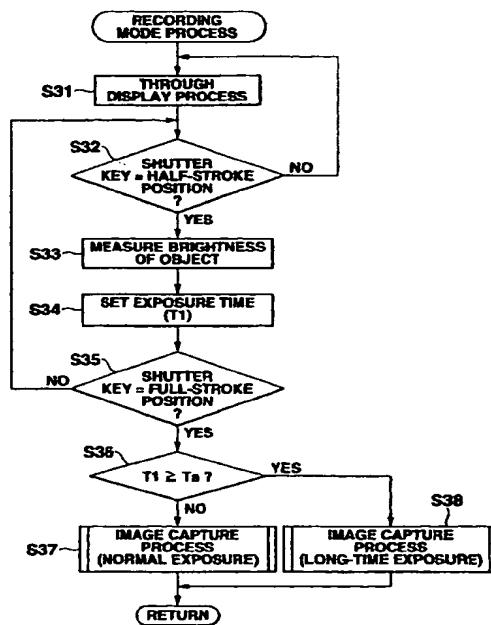
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## (54) Electronic still camera capable of removing noise component in image data and signal processing method thereof

(57) Upon depression of a shutter key of a key input unit (26), a sensed image (DATA1) is captured by exposing a CCD (14) for exposure time T1 with a mechanical shutter (12) opened, and a dark frame image (DATA2) is captured by exposing the CCD (14) for exposure time Ta with the mechanical shutter (12) closed. A correction value corresponding to exposure time T1 is then determined by looking up a correction data table (TBL) stored in a storage area (27a) of a data memory (27), and DATA2 is corrected using the determined correction value. By subtracting the corrected DATA2 from DATA1, a dark output component contained in DATA1 is removed.

FIG.8



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quality and the time required for image sensing can be shortened.

**[0013]** This summary of the invention does not necessarily describe all necessary features so that the invention may also be a sub-combination of these described features.

**[0014]** The invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic block diagram showing the arrangement of an electronic still camera according to the present invention;

FIG. 2 is a schematic view of a CCD having  $n$  (columns)  $\times$   $m$  (rows) pixels, which is used in the electronic still camera shown in FIG. 1;

FIG. 3 is a schematic block diagram of a signal processing LSI including a gamma correction processing circuit, which is used in the electronic still camera shown in FIG. 1;

FIGS. 4A and 4B are graphs showing the characteristics of gamma correction tables respectively having nonlinear and linear characteristics;

FIG. 5 shows the memory area structure of a data memory of the electronic still camera shown in FIG. 1;

FIG. 6 is a graph showing the concept of a correction data table (TBL) stored in the data memory shown in FIG. 5;

FIG. 7 is a general flow chart of a control program of the electronic still camera according to the present invention;

FIG. 8 is a flow chart showing the operation of a control program of a recording mode process shown in FIG. 7;

FIG. 9 is a flow chart (1/4) showing the operation of a control program of an image capture process for long-time exposure shown in FIG. 8;

FIG. 10 is a flow chart (2/4) showing the operation of the control program of the image capture process for long-time exposure shown in FIG. 8;

FIG. 11 is a flow chart (3/4) showing the operation of the control program of the image capture process for long-time exposure shown in FIG. 8;

FIG. 12 is a flow chart (4/4) showing the operation of the control program of the image capture process for long-time exposure shown in FIG. 8;

FIGS. 13A and 13B are flow charts showing the operation of a control program of an image capture process for normal exposure shown in FIG. 8;

FIG. 14 is a flow chart showing the operation of another control program of the recording mode process shown in FIG. 7;

FIGS. 15A to 15C are flow charts showing the operation of another control program of the image capture process for long-time exposure shown in FIG. 8;

FIGS. 16A to 16C are flow charts showing the oper-

ation of still another control program of the image capture process for long-time exposure shown in FIG. 8;

FIG. 17 is a flow chart (1/2) showing the operation of still another control program of the recording mode process shown in FIG. 7;

FIG. 18 is a flow chart (2/2) showing the operation of still another control program of the recording mode process shown in FIG. 7; and

FIGS. 19A to 19C are flow charts showing the operation of still another control program of the image capture process for long-time exposure shown in FIG. 8.

**[0015]** The preferred embodiments of the present invention will be described hereinafter with reference to the accompanying drawing, taking a digital camera as an example.

**[0016]** Referring to FIG. 1, reference numeral 11 denotes a photo lens; 12, a mechanical shutter which is provided on the optical axis of the photo lens 11 and also serves as a stop mechanism; 13, a driving unit for adjusting the degree of opening of the mechanical shutter 12; 14, a CCD for receiving light that has passed through the mechanical shutter 12, and outputting a sensed image signal of an object; 15, a driver for the CCD 14; 16, a timing generator for generating various timing signals such as a signal for controlling the charge accumulation time (to be referred to as an electronic shutter time hereinafter) of the CCD 14 and the like; 17, a correlative double sampling circuit (CDS) for sampling the sensed image signal output from the CCD 14 and removing noise; 18, an analog-to-digital converter (A/D) for converting the sensed image signal after noise removal into a digital signal; and 19, a gamma correction circuit.

**[0017]** Reference numeral 20 denotes a color process circuit for generating a luminance/color difference mixed signal (to be referred to as a YUV signal hereinafter) using the output from the gamma correction circuit 19; 21, a video transfer circuit for arbitrating the flow of signals; 22, a buffer memory for temporarily holding the YUV signal; 23, a compression/expansion circuit for compressing/expanding the YUV signal by a predetermined coding scheme (generally, JPEG (Joint Photographic Experts Group)) upon recording and playback; and 24, a fixed or detachable flash memory for recording the compressed YUV signal.

**[0018]** Reference numeral 25 denotes a CPU (Central Processing Unit) for making various kinds of control required upon recording and playing back an image by loading a control program stored in a program ROM (Read Only Memory) 25a onto a user work RAM (Random Access Memory) 25b and executing the loaded program; and 26, a key input unit for generating a key input signal in response to operation of a shutter button or various function buttons.

**[0019]** Reference numeral 27 denotes a data mem-

**[0029]** When the relationship between the exposure time and correction value can be expressed by a formula such as a linear function formula, quadratic function formula, or the like, only the formula may be held in the data memory 27, and a correction value may be derived by substituting the exposure value in the formula.

**[0030]** The operation will be explained below.

**[0031]** FIG. 7 is a schematic flow chart showing an outline of a control program executed by the CPU 25. Execution of this program begins when a power switch (not shown) of the electronic still camera is turned on. The program executes initialization such as operation checking and the like first (step S21), and then repeats operation for checking the operation mode (recording or playback mode) (step S22), and executing a branch process (a playback mode process in step S23 or a recording mode process in step S24) in accordance with the checking result. Note that other operation modes such as a system setup mode and the like are also available, but a description of such modes will be omitted for the sake of simplicity.

**[0032]** To summarize, the playback mode process reads out the sensed image recorded in the flash memory 24, and plays back and displays it on the liquid crystal display 29, and a detailed description of this process will be omitted since it is not important for the present invention.

**[0033]** FIG. 8 is a flow chart showing the recording mode process program. When this flow chart starts, a display process of a through image (finder image) is executed (step S31), and repeats itself until a "half-stroke" operation of the shutter key is detected (step S32). Note that the through image is a moving picture output from the CCD 14 at a predetermined cycle (e.g., 1/30-sec cycle). When this moving image is displayed on the liquid crystal display 29, the user can easily confirm and adjust the composition.

**[0034]** After that, if a "half-stroke" operation of the shutter key is detected, the brightness of an object is measured using output data from a photometry sensor (not shown) and the CCD 14 (step S33) to compute an optimal exposure time (to be referred to as "T1" for the sake of convenience; unit = seconds), and T1 is set. Also, the degree of opening of the mechanical shutter 12 and the opening/closing timings of the electronic shutter and mechanical shutter 12 are set using T1 (step S34). After that, a "full-stroke" operation of the shutter key is detected (step S35).

**[0035]** If a "full-stroke" operation of the shutter key is detected, it is checked if T1 set in step S34 is equal to or longer than Ta (e.g., 1 sec) (step S36). If NO in step S36, an image capture process for normal exposure (exposure time shorter than long-time exposure to be described later) is executed (step S37); otherwise, an image capture process for long-time exposure is executed (step S38).

**(Image Capture Process (Long-time Exposure))**

**[0036]** FIGS. 9 to 12 are flow charts of the image capture process program for long-time capture. In this flow chart, a linear gamma correction characteristic (second gamma correction characteristic 32) is selected (step S38a). In this manner, the gamma correction circuit 19 has an I/O characteristic based on the linear gamma correction characteristic shown in FIG. 4B, i.e., substantially disables the gamma correction process.

**[0037]** The electronic shutter is then "opened" (step S38b), and the control waits for an elapse of T1. After an elapse of T1, the mechanical shutter 12 and electronic shutter are "closed" (step S38d). Note that the mechanical shutter 12 and electronic shutter need not always be closed at the same timing, and the electronic shutter may be closed after the mechanical shutter 12 is closed or vice versa. Alternatively, the electronic shutter alone may be closed at this timing, and the mechanical shutter 12 may be closed after a CCD image is captured.

**[0038]** In step S38e, a CCD image is captured, and is temporarily stored in the buffer memory 22. If this CCD image is called "DATA1" for the sake of convenience, DATA1 is characterized in that it includes a large dark current component corresponding to exposure time T1 equal to or longer than predetermined time Ta, and does not undergo any gamma correction in the gamma correction circuit 19.

**[0039]** The electronic shutter is "opened" while the mechanical shutter 12 remains "closed" (step S38f), and the control waits for an elapse of predetermined time Ta (step S38g). That is, since Ta is, e.g., 1 sec, as described above, the electronic shutter is "closed" after

an elapse of 1 sec (step S38h) to capture a CCD image (step S38i), and the mechanical shutter 12 (step S38j) is "opened" to store that CCD image in the buffer memory 22 as a dark frame image corresponding to the exposure time of Ta sec (step S38k). In this case, the opening timing of the mechanical shutter 12 is set between the CCD image capture timing in step S38i and the dark frame data storage timing in step S38k, but the mechanical shutter 12 can be opened at any timing after the electronic shutter is closed in step S38h.

**[0040]** If the CCD image stored in the buffer memory 22 in step S38k is called "DATA2" for the sake of convenience, since this DATA2 is a CCD image obtained when the CCD 14 undergoes exposure for Ta sec with the mechanical shutter 12 closed, in other words, with incoming light to the CCD 14 intercepted, this CCD image includes only noise components (dark current component + random noise component) of the CCD 14 corresponding to Ta sec. Therefore, by subtracting this DATA2 from the actually sensed image (DATA1), the noise components including the dark current component can be removed. In this case, the sensed image which is to undergo this subtraction process is limited to the one having exposure time Ta, since

CCD 14 for T1 sec with the mechanical shutter 12 opened, a dark frame image (DATA2) is captured by exposing the CCD 14 for T1 sec with the mechanical shutter 12 closed. Then, when the sensed image (DATA1) is corrected using this dark frame image (DATA2), deterioration of image quality upon image sensing can be avoided by removing DATA2 components (dark current component + random noise component) from DATA1. That is, in the normal exposure process (i.e., an exposure process with exposure time T1 less than predetermined time Ta), since the exposure time of DATA1 is set to be equal to that of DATA2, DATA1 can undergo dark current correction without correcting the dark frame image (DATA2).

**[0055]** In the aforementioned embodiment, white scratch discrimination (step S38p) and discrimination as to whether or not the data level is saturated (step S38r) are made to determine if the subtraction process of DATA2 from DATA1 (step S38s) is required. Alternatively, DATA2 may be unconditionally subtracted from DATA1 without such discrimination processes.

**[0056]** In the aforementioned embodiment, the exposure time (T1) is determined by computing an optimal exposure time on the basis of the brightness of an object measured using output data from the photometry sensor or CCD 14 (see steps S33 and S34 in FIG. 8). Alternatively, the user may arbitrarily set an exposure time (T1) of his or her choice by operating the key input unit 26.

**[0057]** FIG. 14 is a flow chart of the recording mode process program when the user sets the exposure time (T1), i.e., a modification of the recording mode process program shown in FIG. 8.

**[0058]** When this flow chart starts, a display process of a through image (finder image) is executed (step S41), and repeats itself until a shutter speed (exposure) setup mode is set by a mode key provided to the key input unit 26 (step S42) or depression of the shutter key is detected (step S43).

**[0059]** After that, if the shutter speed setup mode is set, exposure time T1 set as a default value or exposure time T1 set in the previous shutter speed setup operation is read out from the data memory 27, and is temporarily stored in the user work RAM 25b as value "n" (step S44).

**[0060]** It is then checked if the user has operated a plus or minus key provided to the key input unit 26 (steps S45 and S46). If the user has operated the plus key, value "n" stored in the user work RAM 25b is incremented by 1 (step S47); if the user has operated the minus key, value "n" stored in the user work RAM 25b is decremented by 1 (step S48).

**[0061]** These processes (steps S45 to S48) repeat themselves until it is determined in step S49 the shutter speed setup mode is canceled by the mode key provided to the key input unit 26.

**[0062]** If cancel of the mode is detected in step S49, value "n" stored in the user work RAM 25b at the time of

cancel is determined as exposure time T1, and is stored in the data memory 27 (step S50). After that, the flow returns to step S41 to restart the through image display process.

**[0063]** Note that exposure time T1 may be set by displaying a selection menu on the liquid crystal display 29, and making the user select a desired exposure time from the menu using given keys.

**[0064]** If depression of the shutter key is detected in step S43, it is checked if exposure time T1 set in step S50 is equal to or longer than Ta (step S51). If NO in step S51, an image capture process for normal exposure is executed (step S52); otherwise, an image capture process for long-time exposure is executed (step S53).

**[0065]** In the image capture process for long-time exposure in the aforementioned embodiment, the exposure time (shutter speed) of DATA2 is fixed at Ta, and the correction amount (correction factor) of DATA2 is controlled to change in correspondence with exposure time T1. By contrast, the correction amount (correction factor) of DATA2 may be fixed, and the exposure time of DATA2 may be controlled to change in correspondence with exposure time T1.

**[0066]** FIGS. 15A to 15C are flow charts of the image capture process program for long-time exposure used when the correction amount (correction factor) of DATA2 is fixed, and the exposure time of DATA2 is controlled to change in correspondence with exposure time T1, and substantially the same processing steps as those in the aforementioned image capture processing program for long-time exposure (FIGS. 9 to 12) are executed except for the processing steps shown in FIGS. 15A to 15C.

**[0067]** More specifically, after the linear  $\gamma$  correction characteristic is selected in step S38a in FIG. 9, the flow advances to the processing step in FIG. 15A to determine exposure time T2 of DATA2 on the basis of exposure time T1 of DATA1 and fixed correction factor Ka (e.g., 2x) of DATA2. The flow then returns to step S38b in FIG. 9 to "open" the electronic shutter. Note that the method of computing exposure time T2 is not limited to the aforementioned method. For example, a correspondence table of exposure times T1 and T2, which is similar to that described above using FIGS. 5 and 6 may be held, and exposure time T2 may be computed by looking up this correspondence table.

**[0068]** After the electronic shutter is "opened" in step S38f in FIG. 10, the flow advances to the processing step in FIG. 15B, and the control waits for an elapse of time T2 determined in the processing step in FIG. 15A. The flow then returns to step S38h in FIG. 10 to "close" the electronic shutter.

**[0069]** After the electronic shutter is "opened" in step S38j in FIG. 10, the flow advances to step S61 in FIG. 15C to store a CCD image in the buffer memory 22 as a dark frame image (DATA2) corresponding to exposure time = T2 sec, and the pixel values of DATA2 are

[0083] In step S103, a correction process for removing noise components contained in DATA1 by subtracting DATA2 from DATA1 is executed. That is, in step S103 the same processes as those from step S38n in FIG. 11 to step S38w in FIG. 12 are executed.

[0084] DATA1 then undergoes a software gamma correction process (step S104) and a compression process by the compression/expansion circuit 23 (step S105). After that, DATA1 is recorded in the flash memory 24 (step S106), thus ending the program.

[0085] Note that the processes in steps S100 to S102 may be executed before a full-stroke operation of the shutter key (step S94), i.e., immediately after dark frame data is stored (step S93).

[0086] In this case, only exposure time T2 or both exposure time T2 and correction value may be controlled to change in correspondence with exposure time T1.

[0087] Also, in this case the user may arbitrarily set exposure time T1.

[0088] In the aforementioned embodiment, upon correcting DATA2, DATA2 stored in the buffer memory 22 is corrected in accordance with exposure time T1. Alternatively, the gamma correction characteristic for a CCD image before being stored in the buffer memory 22 may be changed by the gamma correction circuit 19 in accordance with exposure time T1 or the AGC gain of a CCD image before being stored in the buffer memory 22 may be increased by the CDS 17 in accordance with exposure time T1.

[0089] FIGS. 19A to 19C are flow charts of the image capture process program for long-time exposure used when DATA2 is corrected by changing the gamma correction characteristic (FIGS. 19A and 19C) and by adjusting the AGC gain (FIGS. 19B and 19C), and substantially the same processing steps as those in the aforementioned image capture processing program for long-time exposure (FIGS. 9 to 12) are executed except for the processing steps shown in FIGS. 19A to 19C.

[0090] More specifically, when DATA2 is corrected by changing the gamma correction characteristic, after a CCD image (DATA1) is captured in step S38e in FIG. 9, the flow advances to the processing step in FIG. 19A to change the slope of the gamma correction characteristic of the gamma correction circuit 19 in accordance with exposure time T1. The flow then returns to step S38f in FIG. 10 to "open" the electronic shutter.

[0091] After the electronic shutter is "opened" in step S38j in FIG. 10, the flow advances to the processing step in FIG. 19C to store a CCD image in the buffer memory 22 as a dark frame image corresponding to exposure time T1. The flow then returns to step S38n in FIG. 11.

[0092] That is, the processing step in FIG. 19A is inserted between step S38e in FIG. 10 and step S38f in FIG. 11, "Ta" in processing step S38k in FIG. 10 is changed to "T1", and processing steps S38l and S38m are omitted.

[0093] Likewise, when DATA2 is corrected by

adjusting the AGC gain, after a CCD image (DATA1) is captured in step S38e in FIG. 9, the flow advances to the processing step in FIG. 19B to change the gain of an AGC gain adjustment circuit in the CDS 17 in accordance with exposure time T1. The flow then returns to step S38f in FIG. 10 to "open" the electronic shutter.

[0094] After the electronic shutter is "opened" in step S38j in FIG. 10, the flow advances to the processing step in FIG. 19C to store a CCD image in the buffer memory 22 as a dark frame image corresponding to exposure time T1. The flow then returns to step S38n in FIG. 11.

[0095] That is, the processing step in FIG. 19B is inserted between step S38e in FIG. 10 and step S38f in FIG. 11, "Ta" in processing step S38k in FIG. 10 is changed to "T1", and processing steps S38l and S38m are omitted.

[0096] In the aforementioned embodiment, when the camera user has pressed the shutter key to its full-stroke position to instruct image sensing, a sensed image (DATA1) and dark frame image (DATA2) are captured (sensed). However, when, for example, image sensing is automatically instructed like in timer image sensing at a fixed point, a sensed image (DATA1) and dark frame image (DATA2) may be captured (sensed).

[0097] In the aforementioned embodiment, after the camera user has pressed the shutter key to its full-stroke position to instruct image sensing, a sensed image (DATA1) is captured (sensed). However, other data, for example, sensed image data that has already been captured to display a through image immediately before image sensing is instructed may be used as DATA1.

[0098] In the aforementioned embodiment, as a correction process method for removing a dark output component included in DATA1, the CPU 25 subtracts DATA2 from DATA1 by software. However, the present invention is not limited to such specific process, but may use other correction process method, e.g., a process method for removing a dark output component by a hardware process using a subtraction circuit.

## Claims

[0099] 1. An electronic still camera characterized by comprising:

image sensing means (14) for accumulating a charge corresponding to incoming light, converting the accumulated charge into image data, and outputting the image data; optical path opening/closing means (12) for opening/closing an incoming optical path to said image sensing means (14); image sensing instruction means (25, 26) for instructing image sensing; first image sensing control means (13, 15, 16, 25) for, when image sensing is instructed by

corrects the second image data using the read-out correction value.

11. A camera according to claim 9, characterized in that said second image sensing control means (13, 15, 16, 25) captures the second image data by exposing said image sensing means (14) for a fixed time with said optical path opening/closing means (12) closed.

12. A camera according to claim 1, characterized in that said second image sensing control means (13, 15, 16, 25) captures the second image data by exposing said image sensing means (14) for an exposure time corresponding to the first exposure time with said optical path opening/closing means (12) closed.

13. A camera according to claim 12, characterized in that said first correction means (17, 19, 22, 25, 27) corrects the second image data captured by said second image sensing control means (13, 15, 16, 25) using a fixed correction value.

14. A camera according to claim 1, characterized in that said second image sensing control means (13, 15, 16, 25) captures the second image data by exposing said image sensing means (14) for an exposure time corresponding to the first exposure time with said optical path opening/closing means (12) closed, and

35 said first correction means (17, 19, 22, 25, 27) corrects the second image data captured by said second image sensing control means (13, 15, 16, 25) in accordance with the first exposure time.

15. A camera according to claim 1, characterized by further comprising:

40 fourth image sensing control means (13, 15, 16, 25) for, when said image sensing instruction means (26) instructs image sensing, controlling said first image sensing control means (13, 15, 16, 25) to capture the first image data, and then controlling said second image sensing control means (13, 15, 16, 25) to capture the second image data.

50 16. A camera according to claim 1, characterized by further comprising:

55 image data storage means (22) for storing the second image data captured by said second image sensing control means (13, 15, 16, 25), and wherein said first correction means (17, 19, 22,

25, 27) corrects the second image data stored in said image data storage means (22).

17. A camera according to claim 1, characterized by further comprising:

gamma correction means (19, 19d, 19e) for making gamma correction of image data output from said image sensing means (14), and wherein said first correction means (17, 19, 22, 25, 27) corrects the second image data by changing a gamma correction characteristic of said gamma correction means (19, 19d, 19e).

18. A camera according to claim 1, characterized by further comprising:

adjustment means (17) for adjusting a signal level of image data output from said image sensing means (14), and wherein said first correction means (17, 19, 22, 25, 27) corrects the second image data by changing a signal adjustment level of said adjustment means (17).

19. An electronic still camera characterized by comprising:

an image sensing element (14) for accumulating a charge corresponding to incoming light, converting the accumulated charge into image data, and outputting the image data; an optical path opening/closing member (12) for opening/closing an incoming optical path to said image sensing element (14); an image sensing instruction member (26) for instructing image sensing; first image sensing control means (13, 15, 16, 25) for capturing first image data by exposing said image sensing element (14) for a first exposure time with said optical path opening/closing member (12) opened, upon depression of said image sensing instruction member (26); second image sensing control means (13, 15, 16, 25) for capturing second image data by exposing said image sensing element for a second exposure time shorter than the first exposure time with said optical path opening/closing member (12) closed, upon depression of said image sensing instruction member; first correction means (17, 19, 22, 25, 27) for correcting the second image data captured by said second image sensing control means (13, 15, 16, 25); and second correction means (22, 25) for correcting the first image data captured by said first image sensing control means (13, 15, 16, 25)

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FIG.

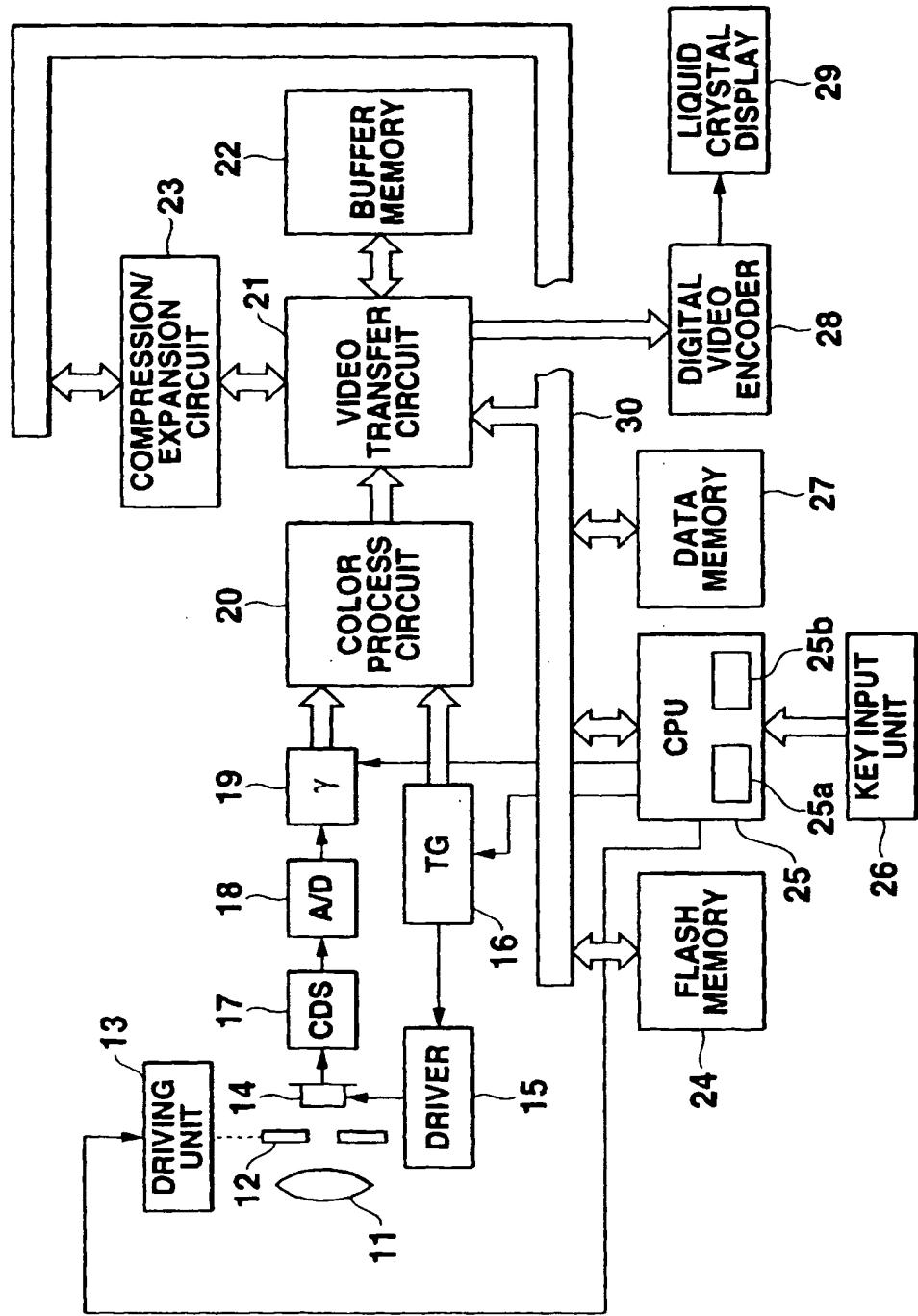
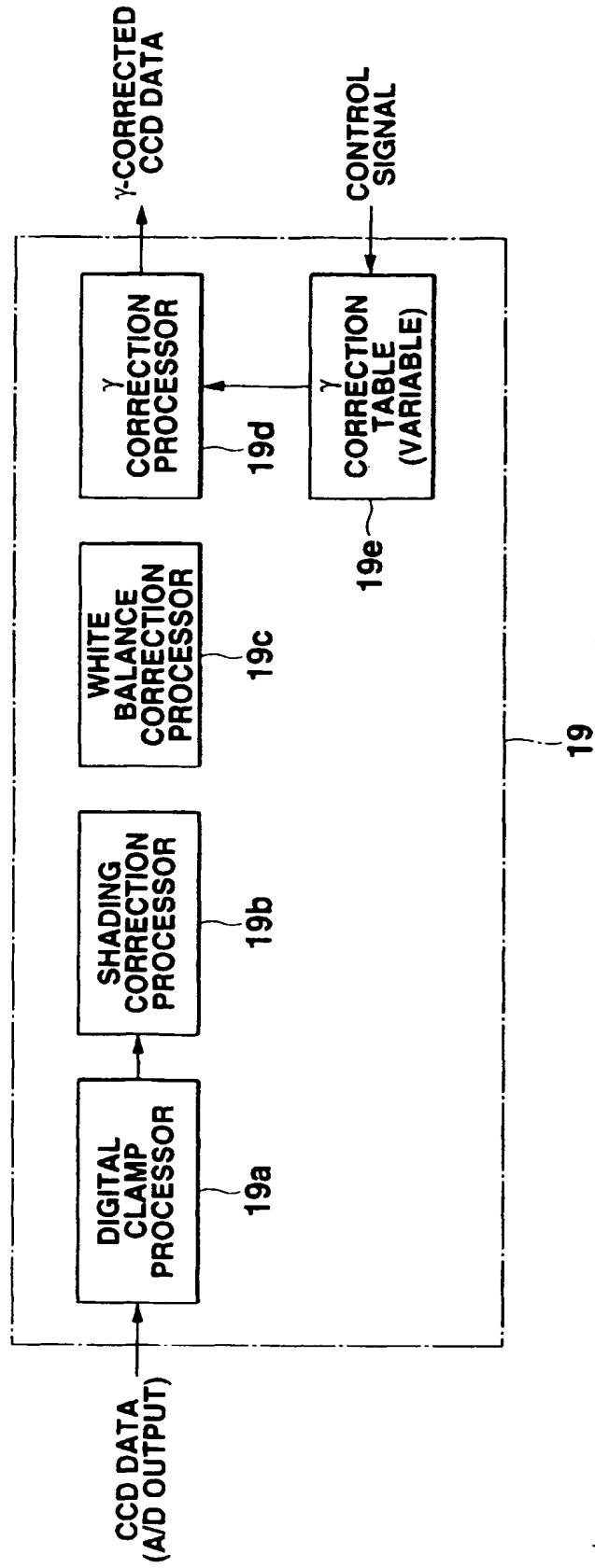
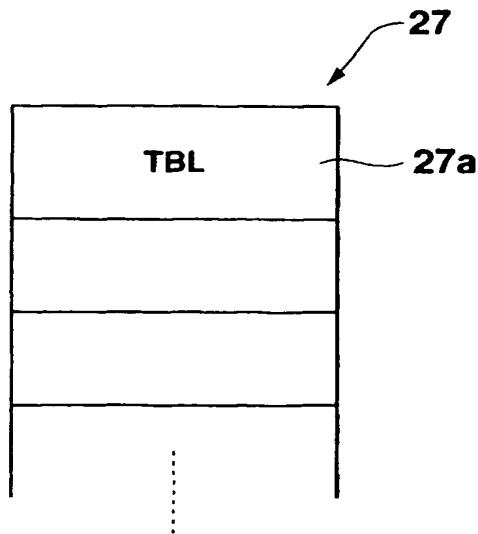


FIG.3



**FIG.5**



**FIG.6**

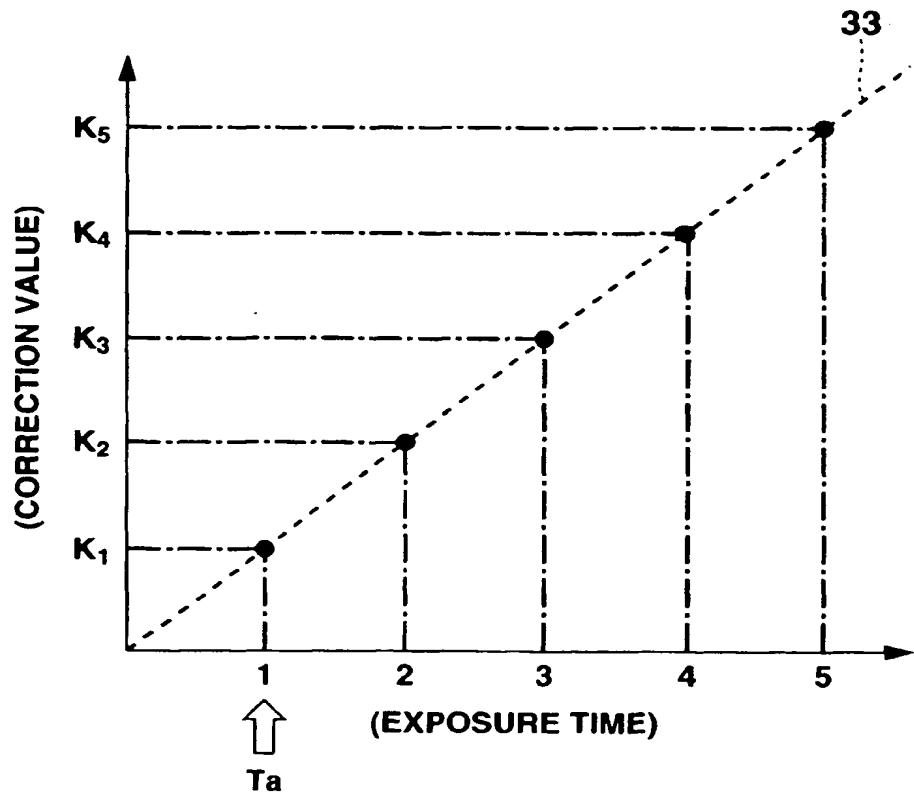


FIG.8

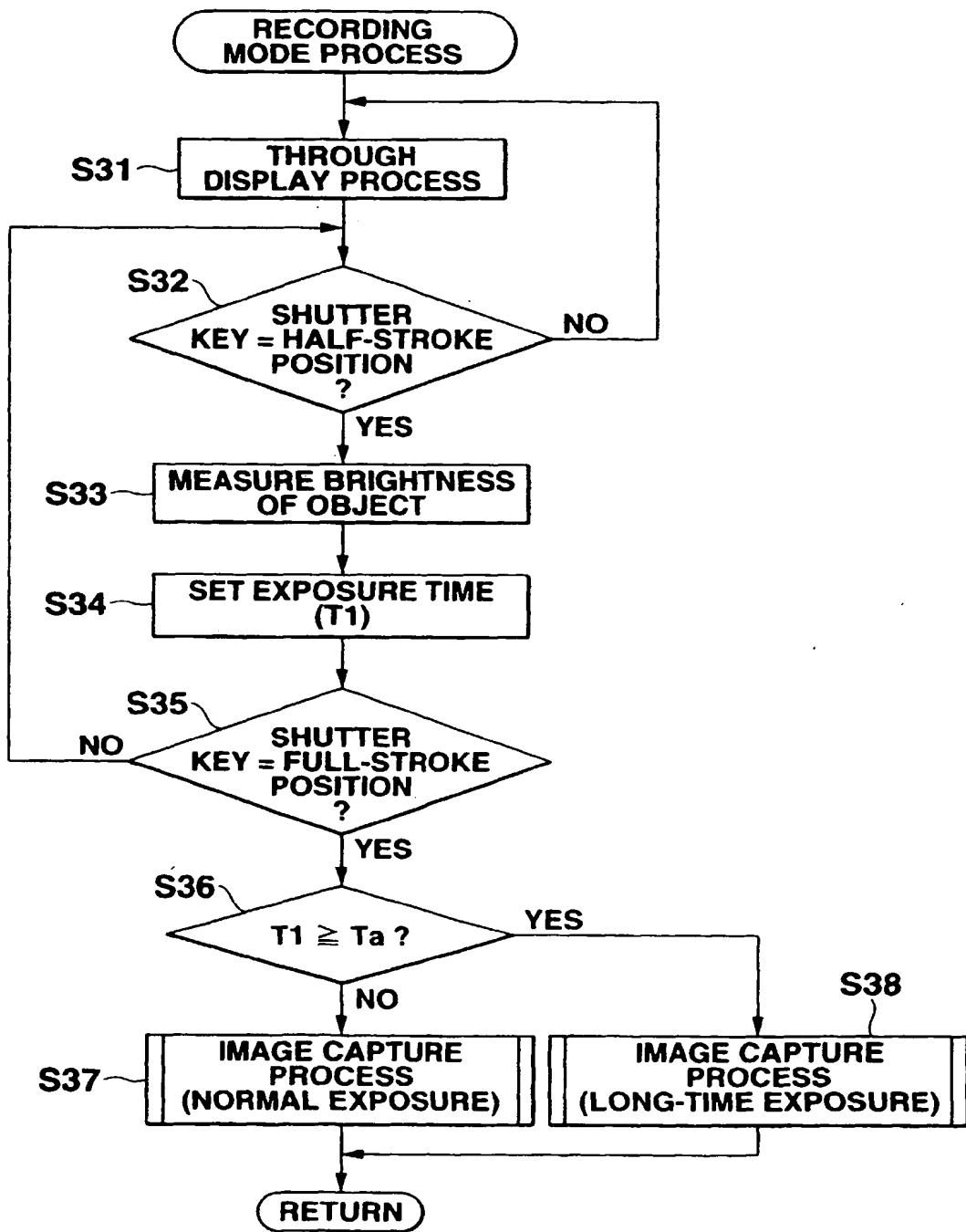


FIG.10

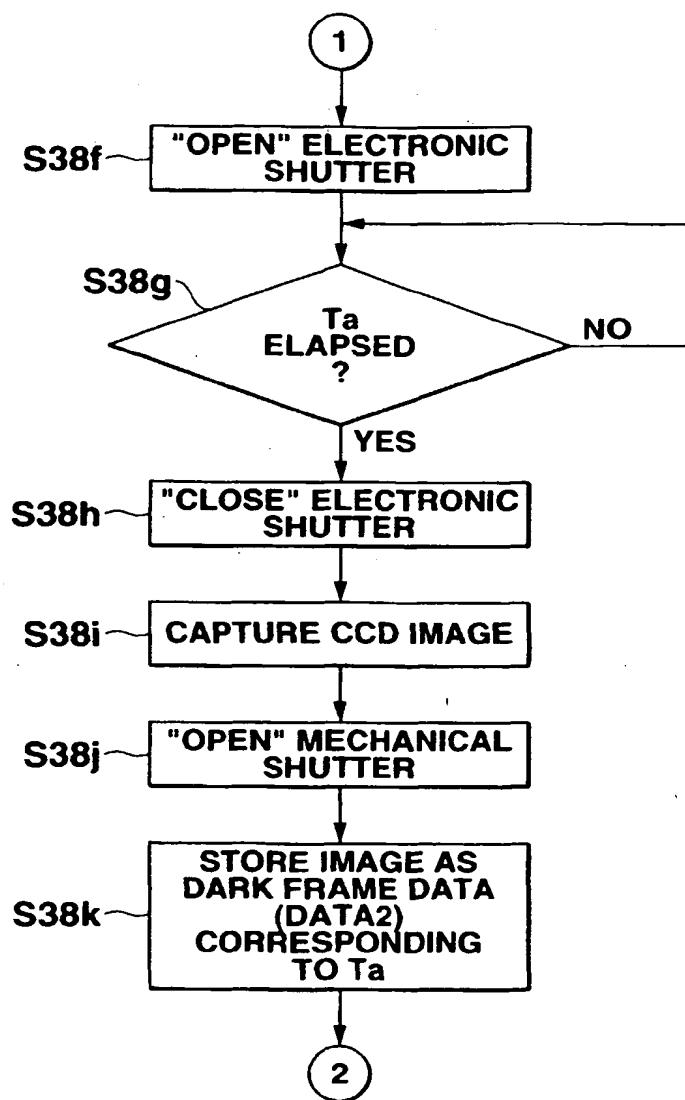


FIG.12

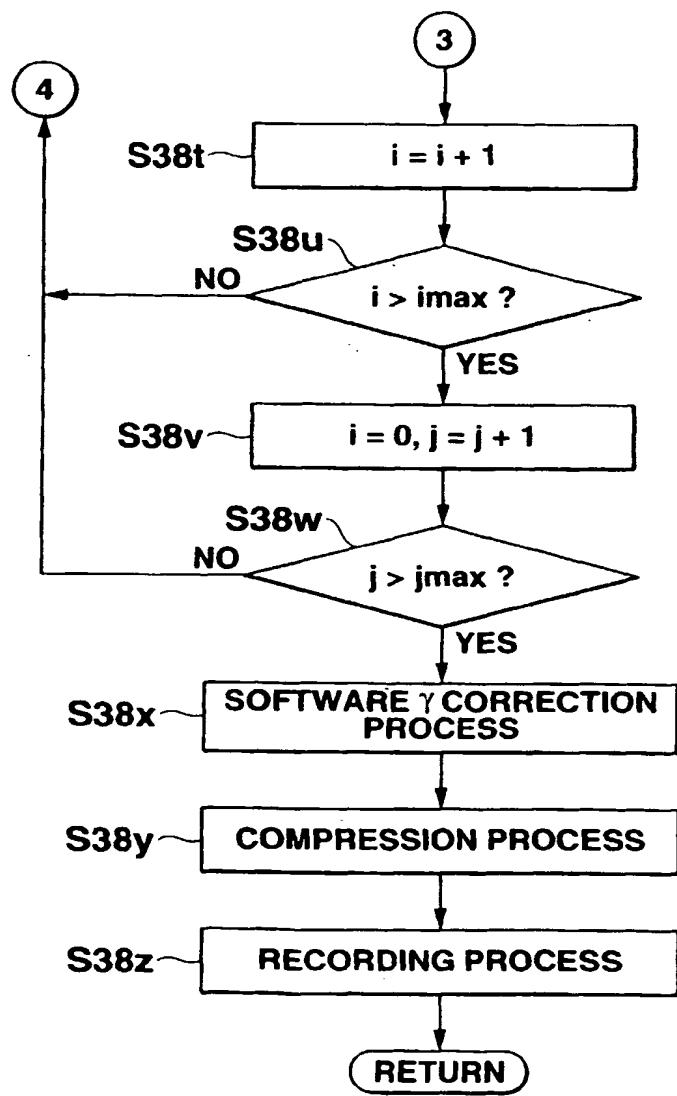
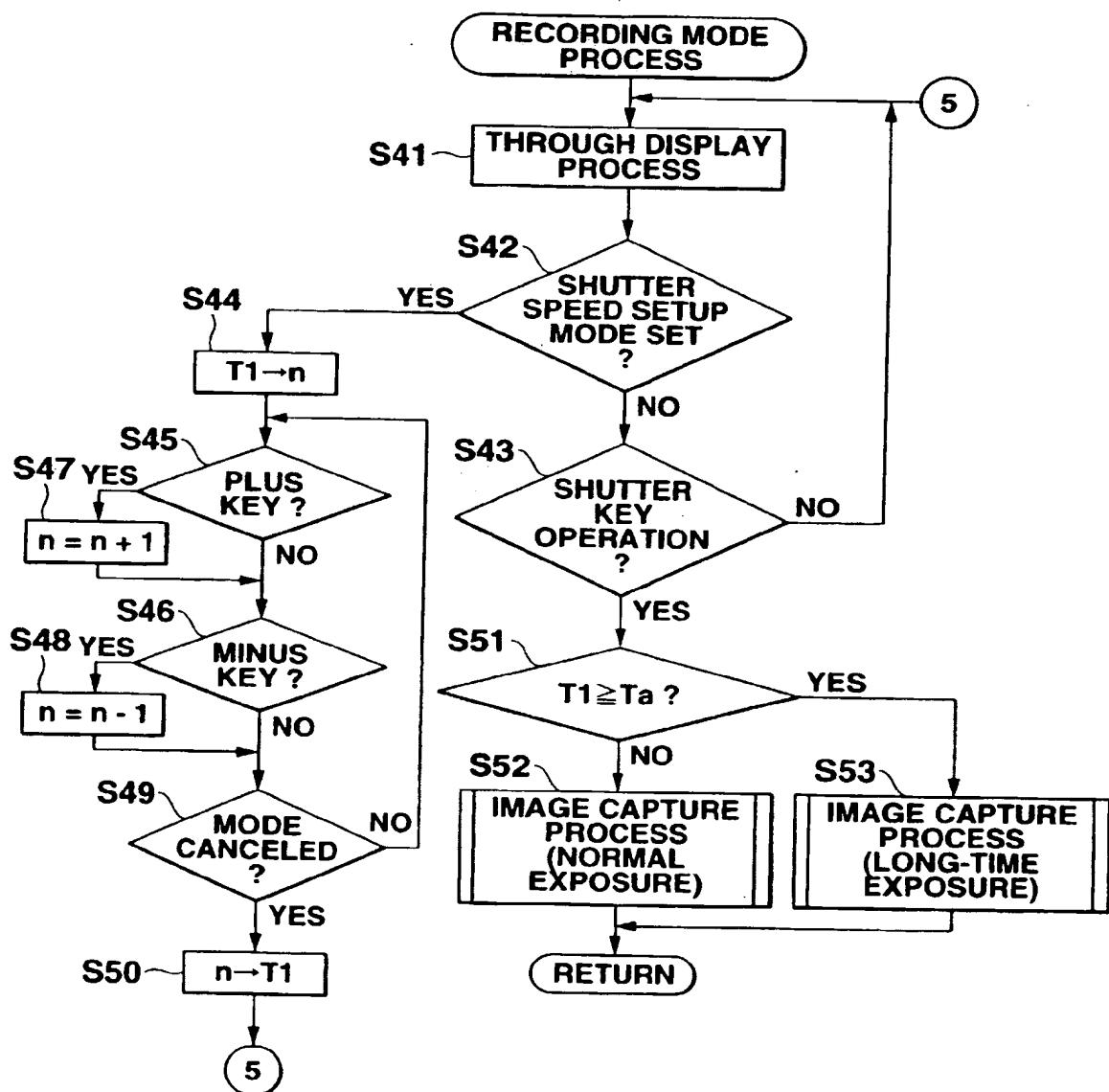
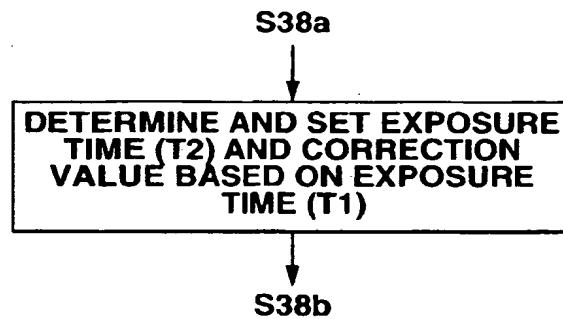


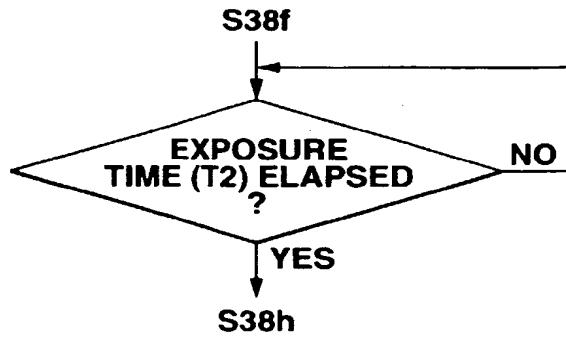
FIG.14



**FIG.16A**



**FIG.16B**



**FIG.16C**

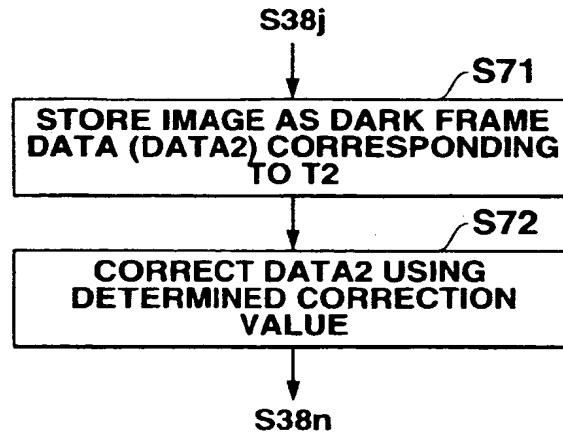
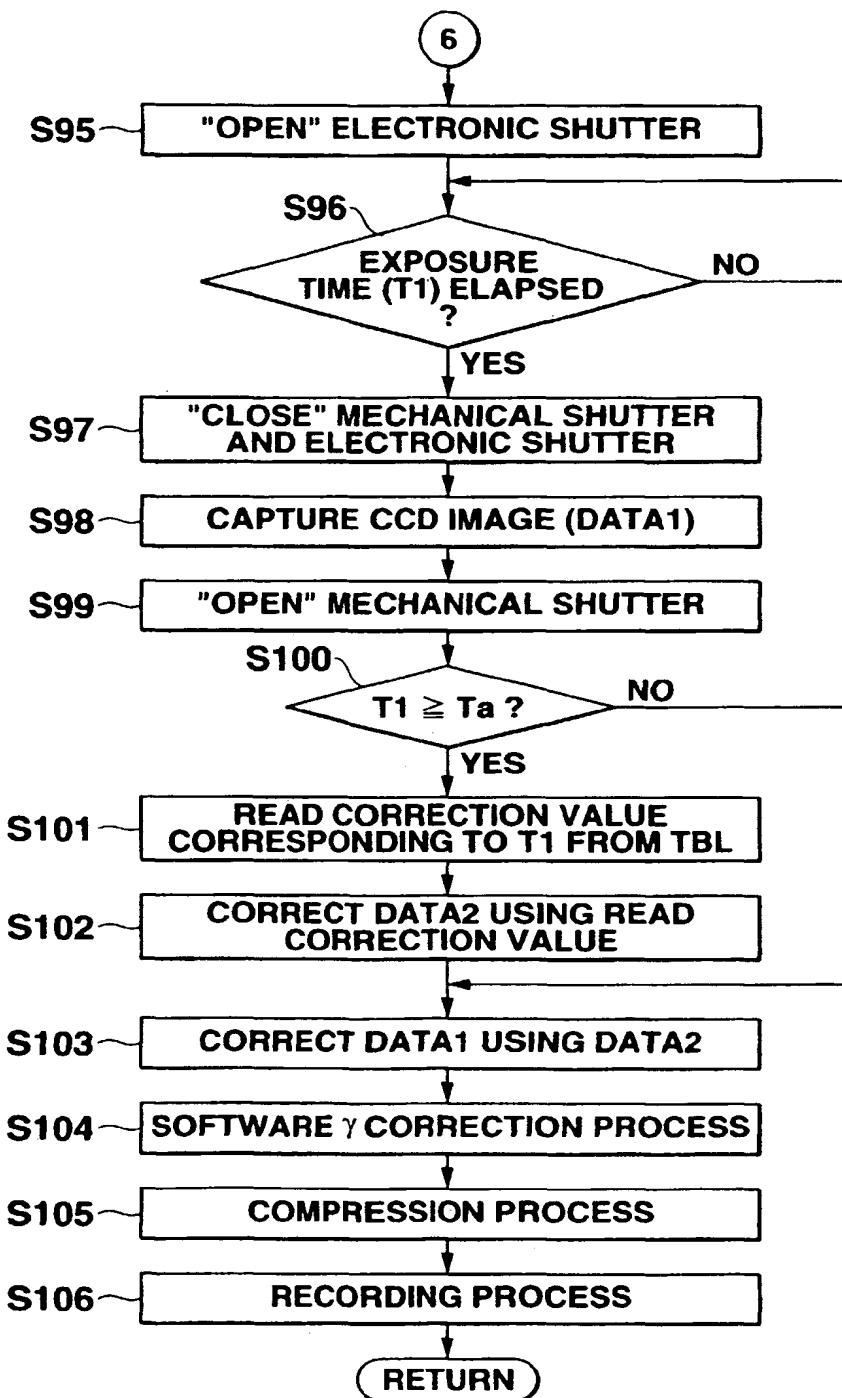


FIG.18





(19)

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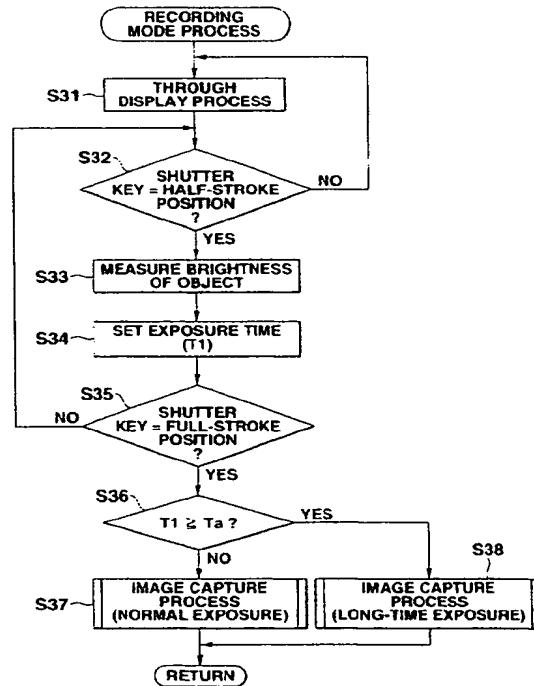
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(54) **Electronic still camera capable of removing noise component in image data and signal processing method thereof**

(57) Upon depression of a shutter key of a key input unit (26), a sensed image (DATA1) is captured by exposing a CCD (14) for exposure time T1 with a mechanical shutter (12) opened, and a dark frame image (DATA2) is captured by exposing the CCD (14) for exposure time Ta with the mechanical shutter (12) closed. A correction value corresponding to exposure time T1 is then determined by looking up a correction data table (TBL) stored in a storage area (27a) of a data memory (27), and DATA2 is corrected using the determined correction value. By subtracting the corrected DATA2 from DATA1, a dark output component contained in DATA1 is removed.

FIG.8



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**ANNEX TO THE EUROPEAN SEARCH REPORT  
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